USGS's Landsat Communication Network

International EESS Wideband Downlink Workshop

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Orlando, Florida

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Agenda

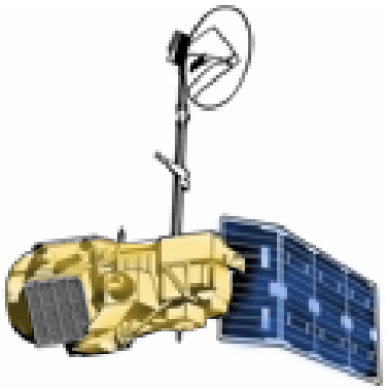
- USGS Landsat Assets (Mission History)
- Landsat Data Application
- Landsat Payload
- Landsat 5 Spacecraft
  - X-band System
  - X-band Helix Current
- Landsat 7 Spacecraft
  - X-band System
- Formation Flying
- Landsat Orbit and Land Coverage
- Telemetry, Tracking, Command, and Data Retrieval
  - Landsat Ground Network
  - Landsat 5 and 7 Reception Network with X-band coverage area
- X-band Downlink Optimization
  - Optimal Antenna Selection (OAS)
- Additional Transmit and Receive Information (Not to be presented)

Landsat Mission History

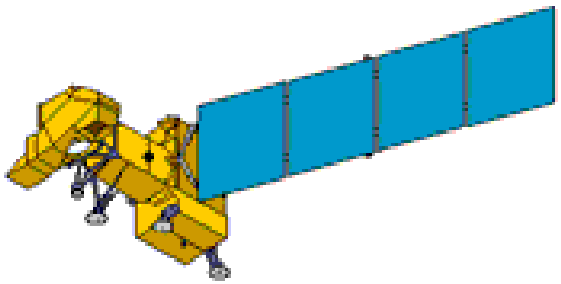
System	Launch (End of service)	I(s)	Resolution (meters)	Communications	Alt. Km	R Days	D Mbps
Landsat 1	7/23/72 (1/6/78)	RBV MSS	80 80	Direct downlink with recorders	917	18	15
Landsat 2	1/22/75 (2/25/82)	RBV MSS	80 80	Direct downlink with recorders	917	18	15
Landsat 3	3/5/78 (3/31/83)	RBV MSS	30 80	Direct downlink with recorders	917	18	15
Landsat 4*	7/16/82	MSS TM	80 30	Direct downlink TDRSS	705	16	85
Landsat 5	3/1/84	MSS TM	80 30	Direct downlink TDRSS**	705	16	85
Landsat 6	10/5/93 (10/5/93)	ETM	15 (pan) 30 (ms)	Direct downlink with recorders	705	16	85
Landsat 7	4/99	ETM+	15 (pan) 30 (ms)	Direct downlink with recorders (solid state)	705	16	150

I(s) = Instrument(s)
R = Revisit interval
D = Data rate
*TM data transmission failed in August, 1993.
** Current data transmission by direct downlink only. No recording capability.

USGS Missions in Service
USGS Missions Retired

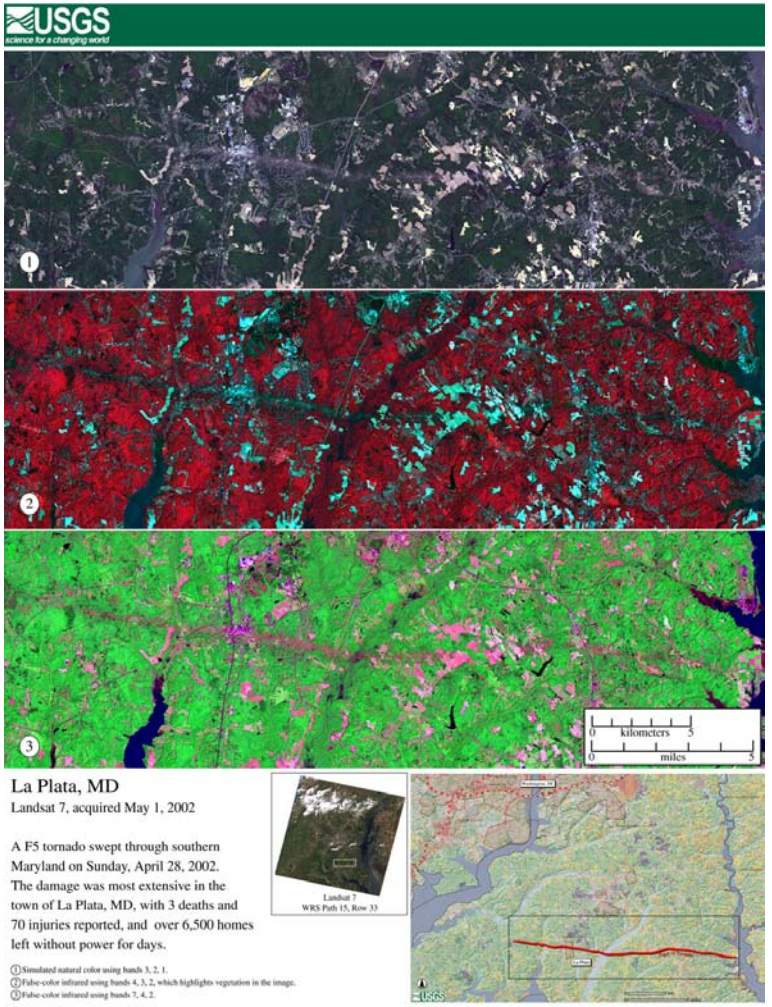


Landsat 5



Landsat 7

Landsat's 5 and 7 Instrument and capability



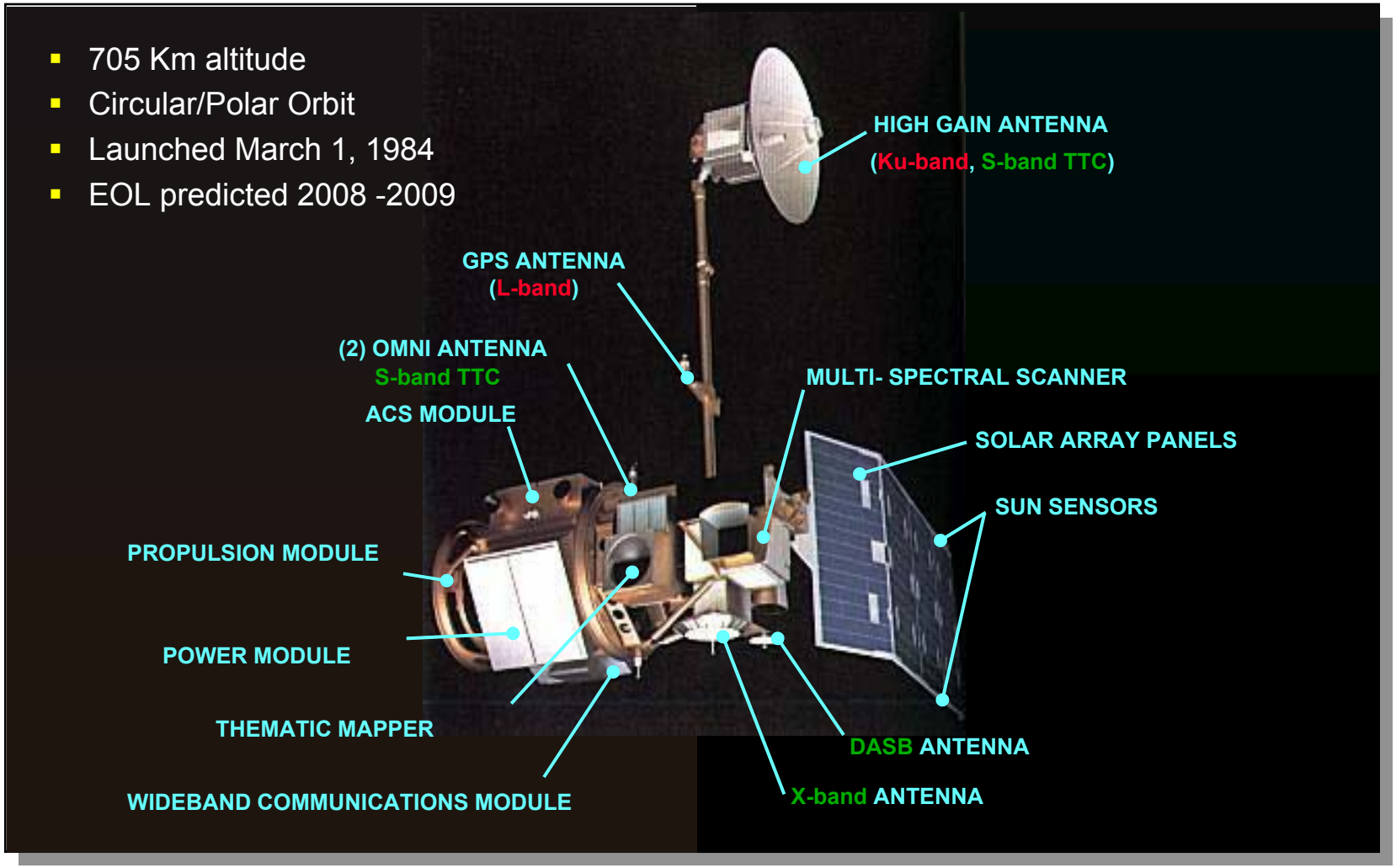
- Uses Include the Following:
  - Land Cover
  - Fire Danger Rating
  - DOI Land Management
  - Natural Hazards
  - Coastal Zones
  - Environmental Monitoring
  - Emergency Response

Landsat 7 Enhanced Thematic Mapper +

- L5's Thematic Mapper and L7's Enhanced Thematic Mapper + are very similar.
- ETM+ 30 m resolution with 15 m Panchromatic sharping band
- 7 bands and a Pan band
- Band 6 is a Thermal Band
- Duty Cycle 16.7% in a day
- 800 scenes viewable
- 600 scenes requested daily
- 400 scenes possible due to operational restrictions

Landsat 5 Spacecraft

- 705 Km altitude
- Circular/Polar Orbit
- Launched March 1, 1984
- EOL predicted 2008 -2009



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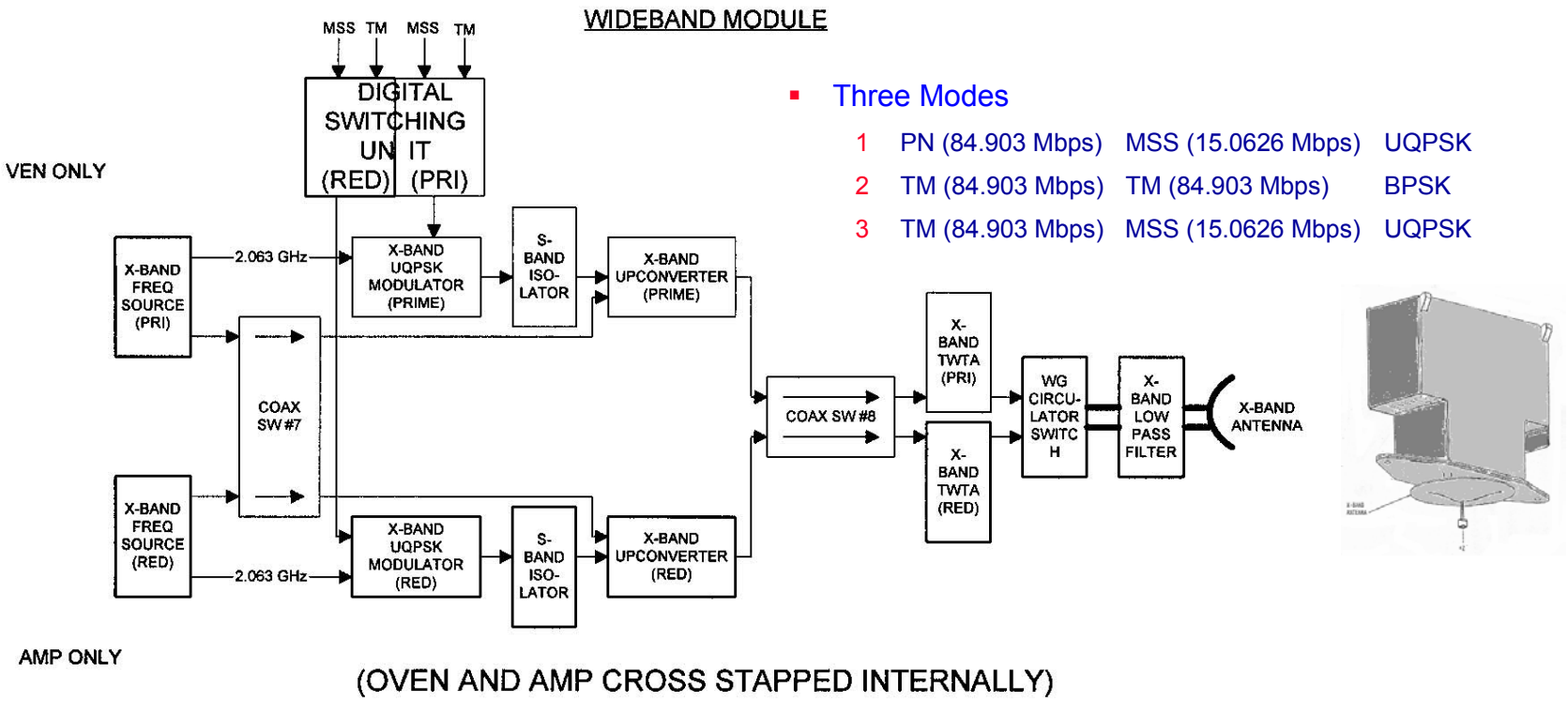
Landsat 5 X-band System: Transmit Only

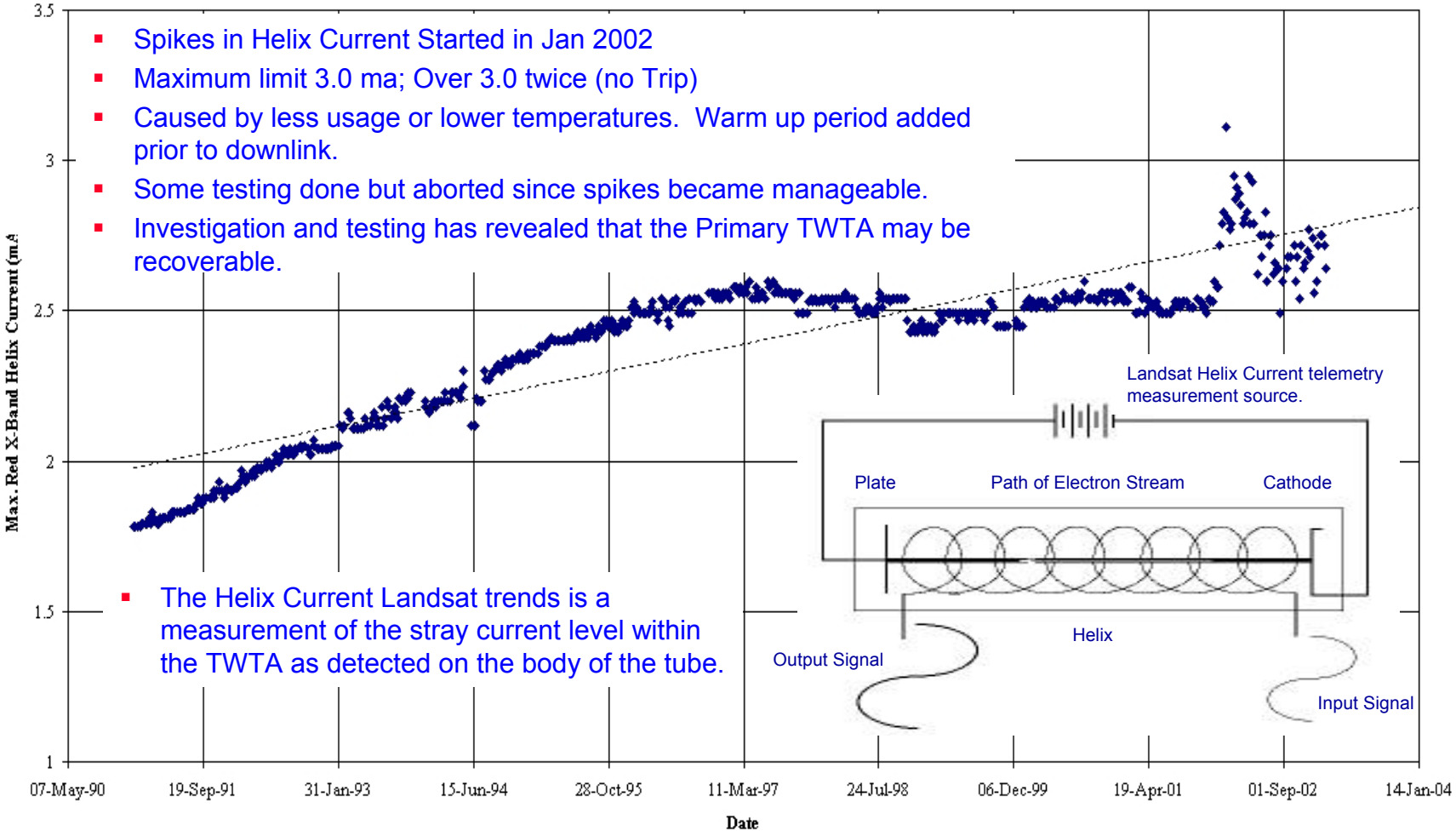


- Three Modes
  - 1 PN (84.903 Mbps) MSS (15.0626 Mbps) UQPSK
  - 2 TM (84.903 Mbps) TM (84.903 Mbps) BPSK
  - 3 TM (84.903 Mbps) MSS (15.0626 Mbps) UQPSK

- Frequency 8212.5 MHz
- Polarization: RHCP
- Transmitter Power: 44 watts
- Shaped Beam antenna (OMNI) which provides a constant EIRP over the illuminated surface of the Earth.
- The TM data on the I carrier channel and the MSS data on the Q carrier channel with a 4-to-1 power split

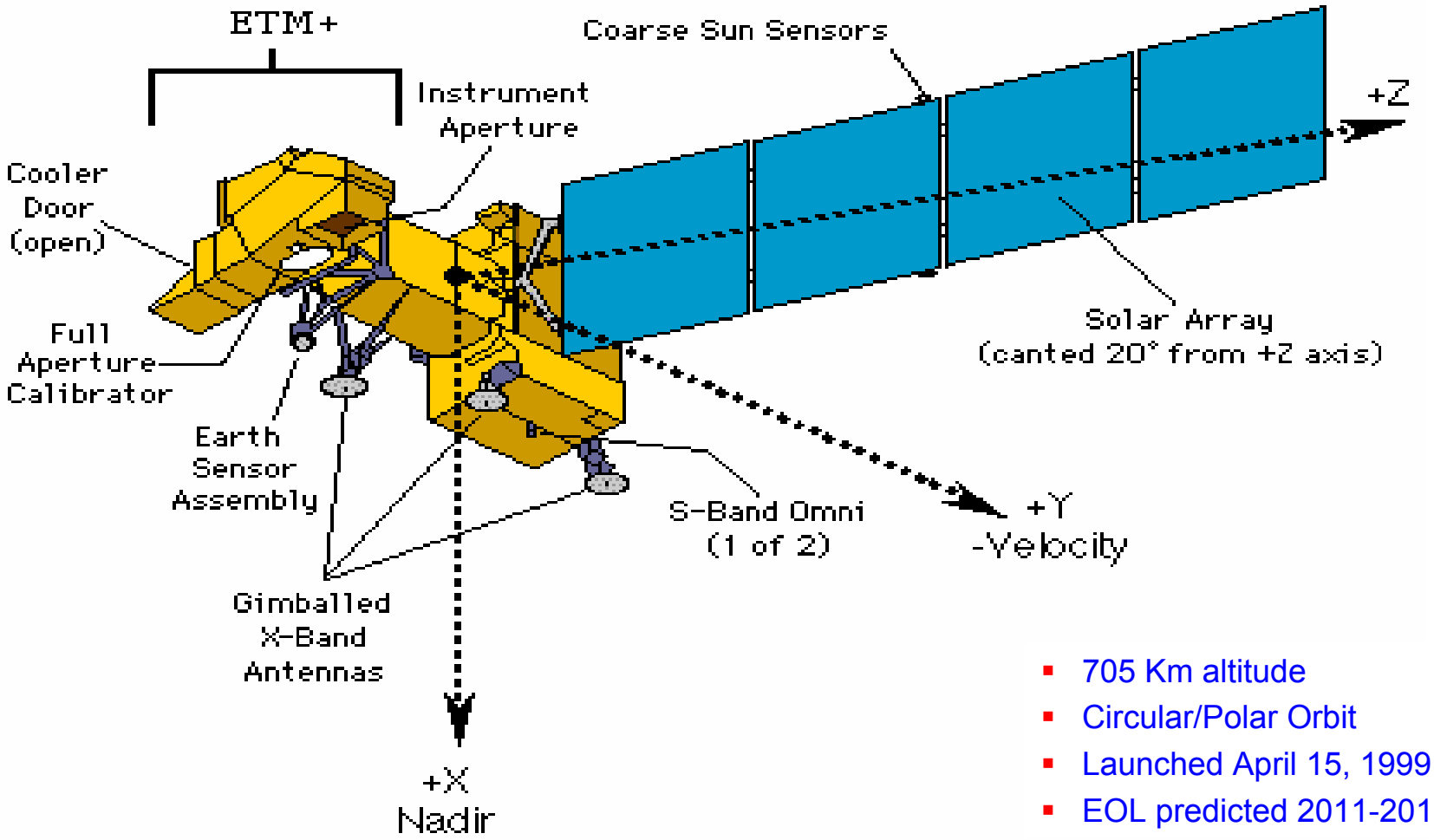
Landsat 5 X-band Helix Current

- Spikes in Helix Current Started in Jan 2002
- Maximum limit 3.0 ma; Over 3.0 twice (no Trip)
- Caused by less usage or lower temperatures. Warm up period added prior to downlink.
- Some testing done but aborted since spikes became manageable.
- Investigation and testing has revealed that the Primary TWTA may be recoverable.



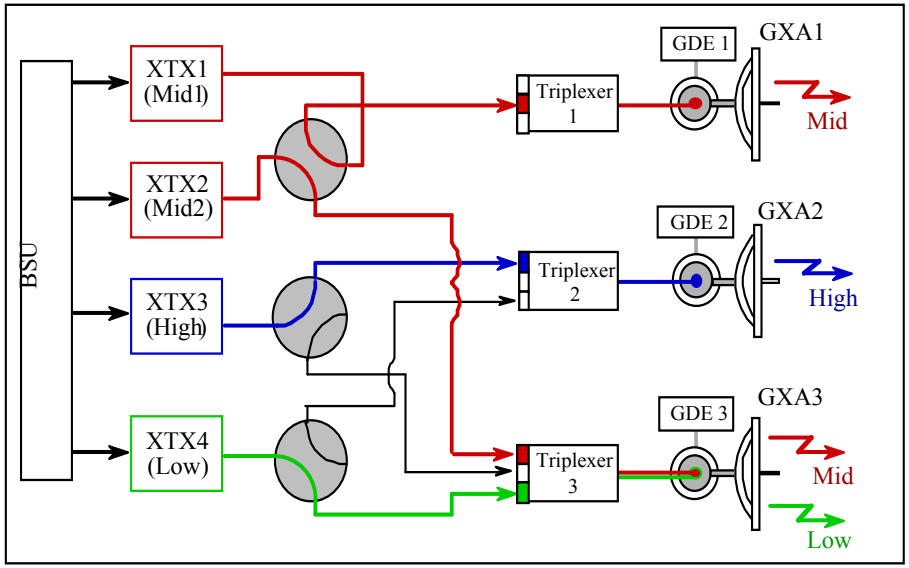
- The Helix Current Landsat trends is a measurement of the stray current level within the TWTA as detected on the body of the tube.

Landsat 7 Spacecraft



- 705 Km altitude
- Circular/Polar Orbit
- Launched April 15, 1999
- EOL predicted 2011-2012

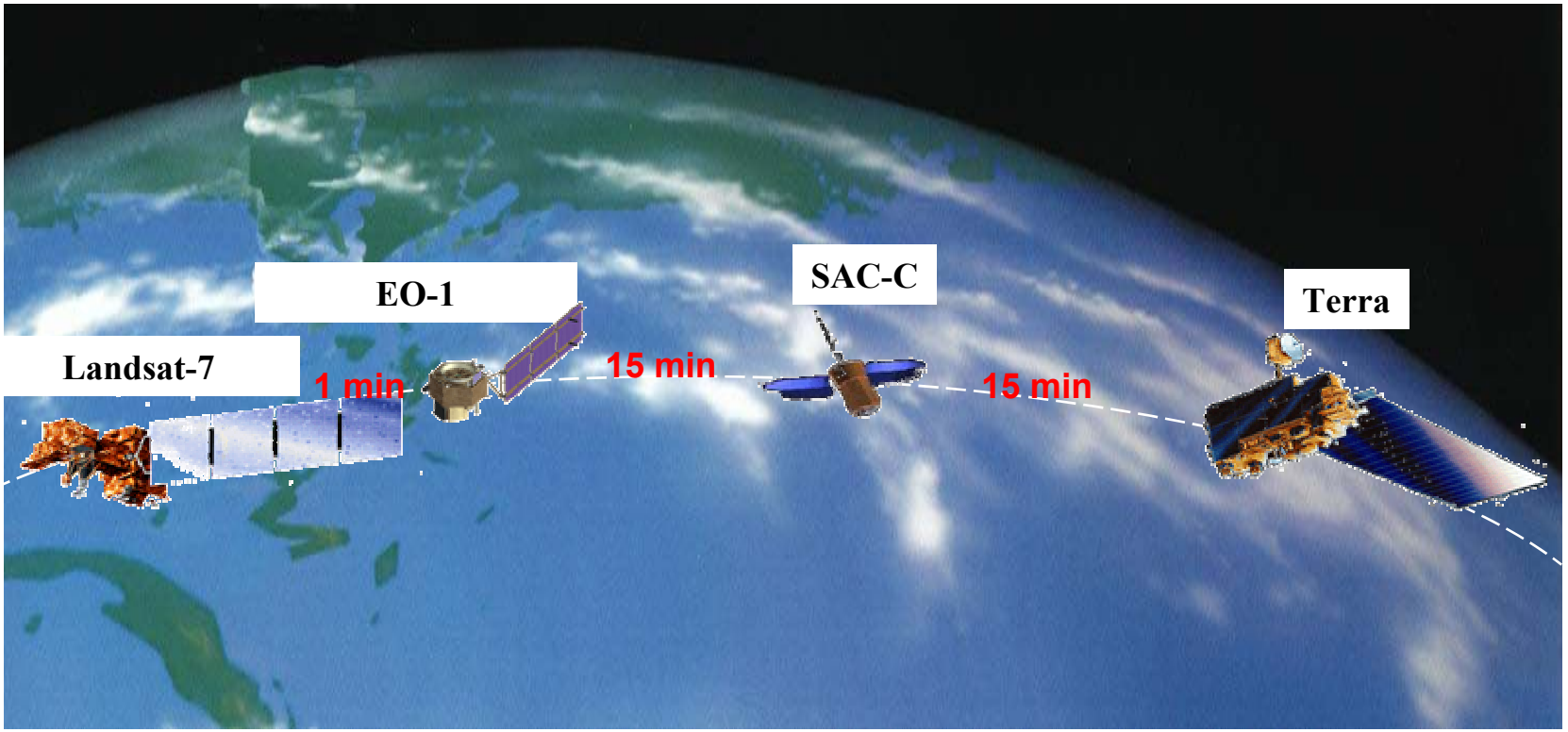
Landsat 7 X-band System: Transmit Only



- GXA (Gimbaled X-band Assembly)
  - Three GXA's radiate narrow beam-width X-Band signals and track ground stations.
  - Each 14.5 inch diameter parabolic dish is steerable.
  - The RF output from the GXA is RHCP.
  - The GXAs are controlled by FSW.
  - The GXAs have "soft stops" at 66 degrees with "hard stops" at ±67.6° (along and across).
  - GXA FSW pointing accuracy at 0.102 degrees while potentiometer accuracy at 1.2 degrees.
  - Max slew rate of the GXAs is 2.5 deg/s however FSW limits the rate to 0.55 deg/s.

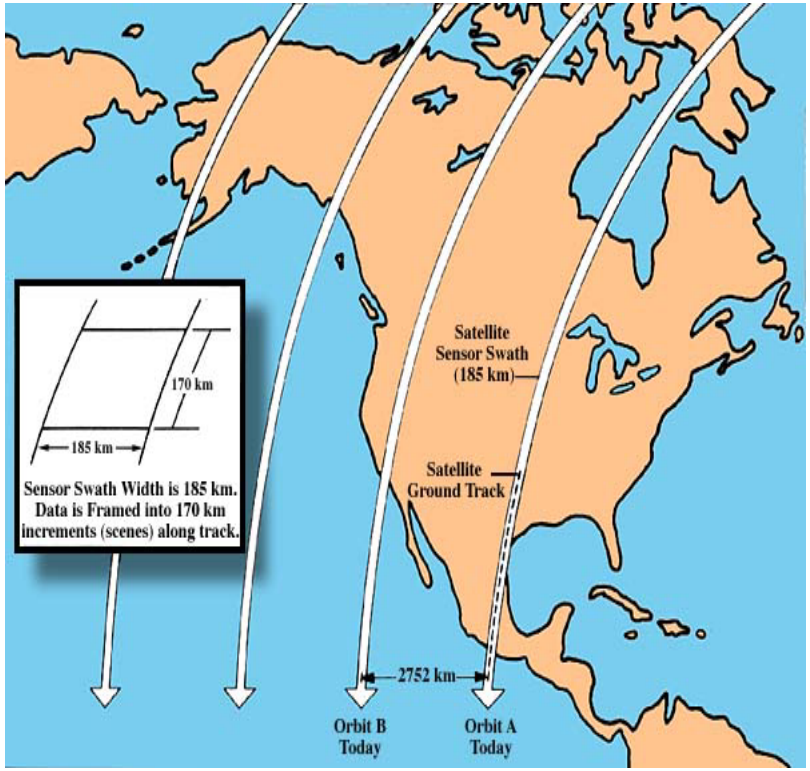
- XTX (X-band Transmitters)
  - Four XTX's provide QPSK modulated data at 150 MBps.
  - Data is received from the BSU in two 75 MBps streams and formatted onto the I and Q channels at a 1:1 ratio.
  - Transmit power is 3.5 Watts.
  - Three frequencies are used: High (8342.5 MHz), Low (8082.5 MHz), and Mid (8212.5 MHz).
  - Two of the transmitters use the same mid frequency, the others are fixed at either high or low.
  - RF "baseball" switch permits all four XTX's to be operating simultaneously through three or fewer antennas.
  - GXA1 can receive one RF signal from either mid XTX, GXA2 can connect to the high and/or low XTX, and GXA3 can receive high and/or mid and/or low (see Figure 6-16.)

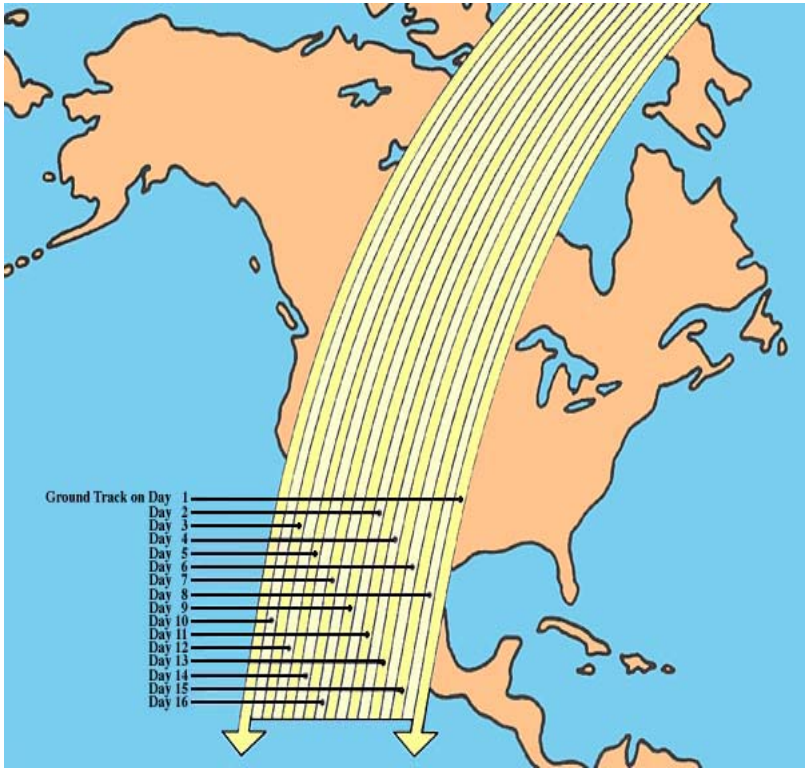
Formation Flying: The Morning Constellation



- Landsat 7 participates in Coincidental Imaging with EO-1, SAC-C, and Terra
- Requires coordination with other missions for observations, orbit maneuvers, pointing, and communications
- Landsat 7 leads this Constellation train and thereby dictates orbital requirements for other missions.

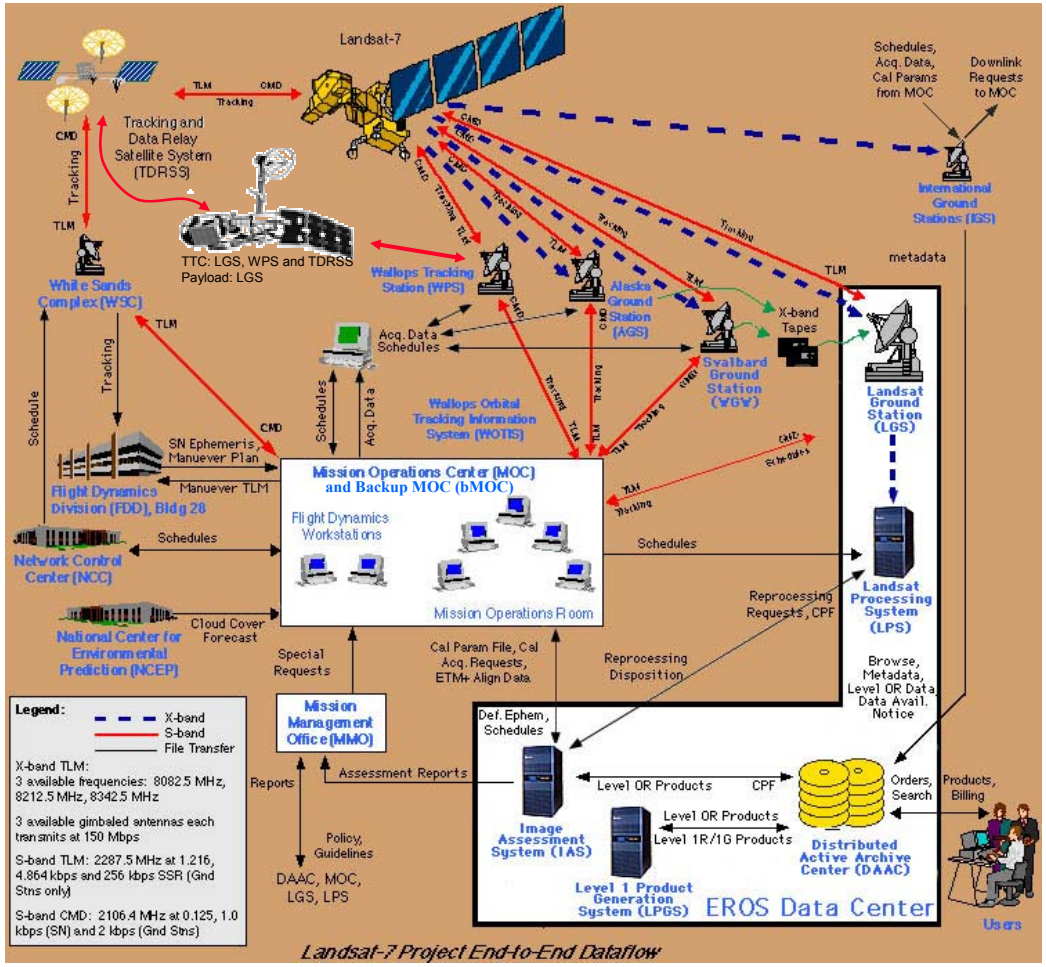
Worldwide Reference System (WRS - 2)





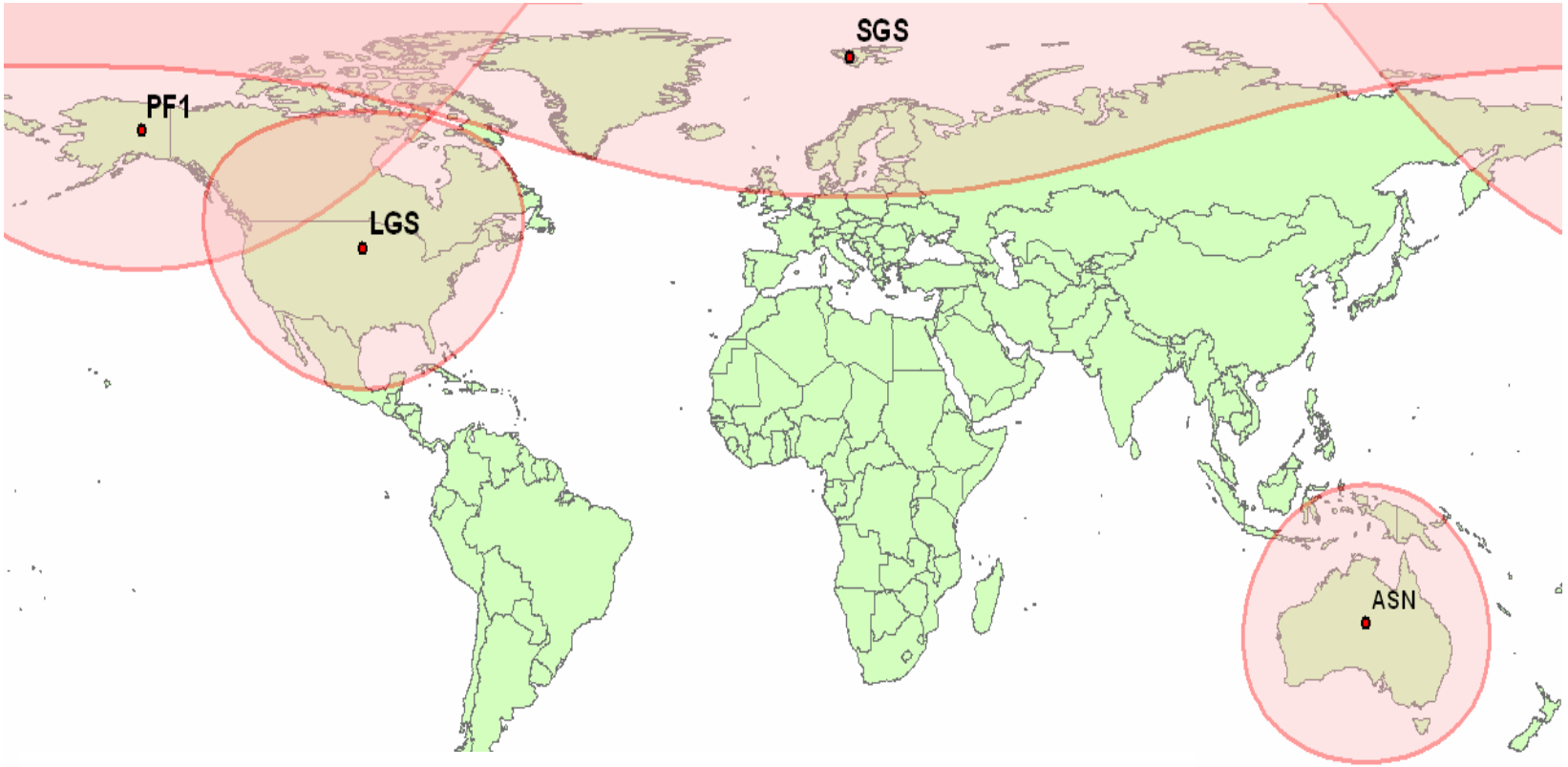
- Landsat 7 passes over the same point of land every 16 days.
- The Worldwide Reference System (WRS) uses Path and Row designations to define a scene.
- The WRS is divided into 233 paths (orbits) and each path is divided into 248 rows (124 day or descending and 124 night or ascending)

Landsat Communication Network



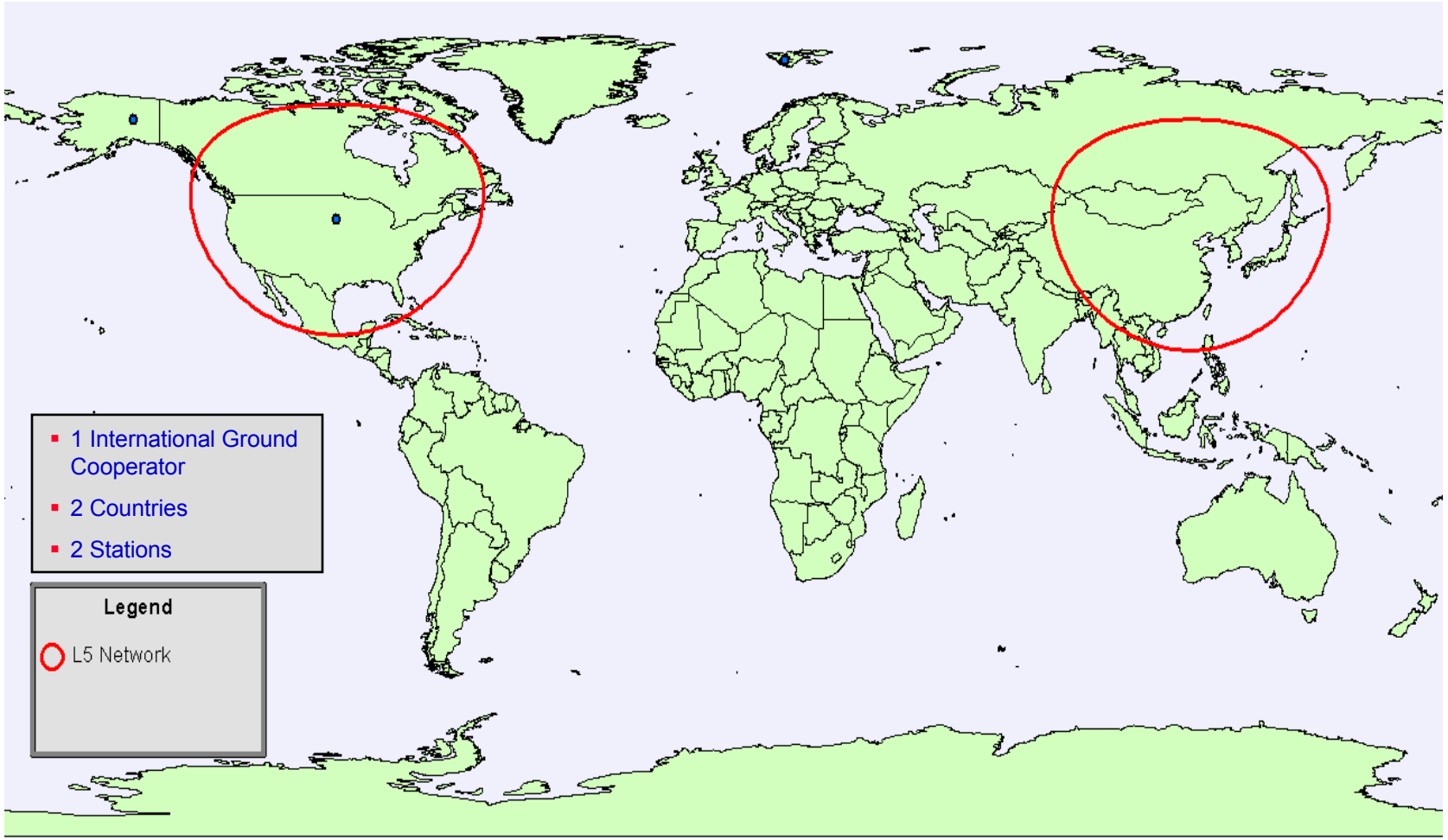
- Average Daily Events (12 month ave)
  - ETM+ imaging intervals – 26.6
  - X-band antenna 1 tracking – 8.4
  - X-band antenna 2 tracking – 9.4
  - X-band antenna 3 tracking – 14.96
  - Recorder p/b's of science data – 7.9
  - X-band transmitters on/off – 39.7
  - S-band transmitters on/off - 20
  - Real-time contacts with MOC - 9
  - Housekeeping data dumps from the recorder - 4

Landsat Ground Network



- Downlinks to Landsat Ground Network
  - ~ 155 scenes per day to EDC (40 per day of USA; 100 per day outside conterminous US)
  - ~ 85 per day to US operated EOS Polar Ground Network (EPGN) stations
    - Poker Flat, AK
    - Svalbaard, Norway
    - Alice Springs, Australia (April 1, 2003)

Landsat 5 Reception Network



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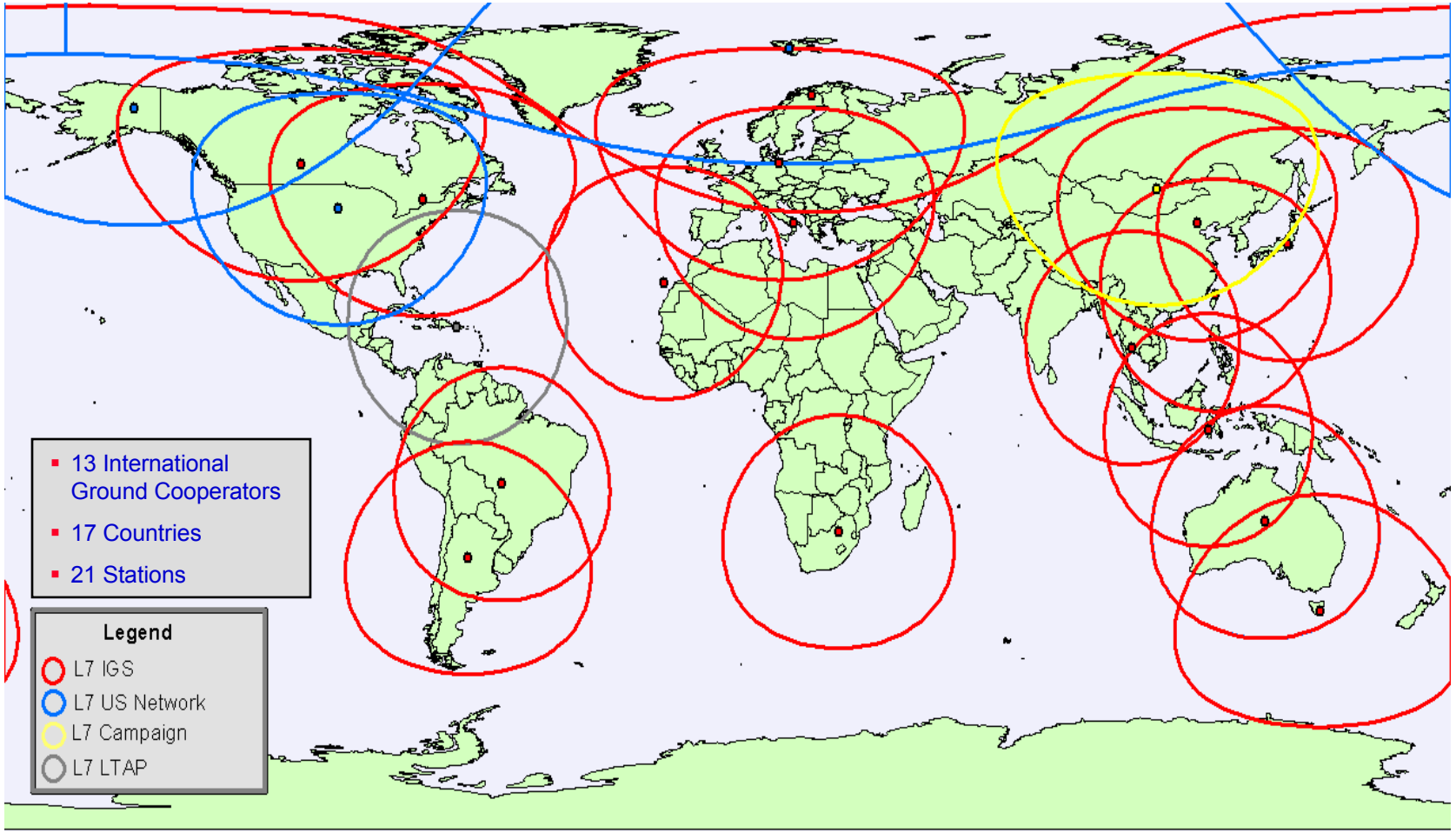
Landsat 7 Reception Network



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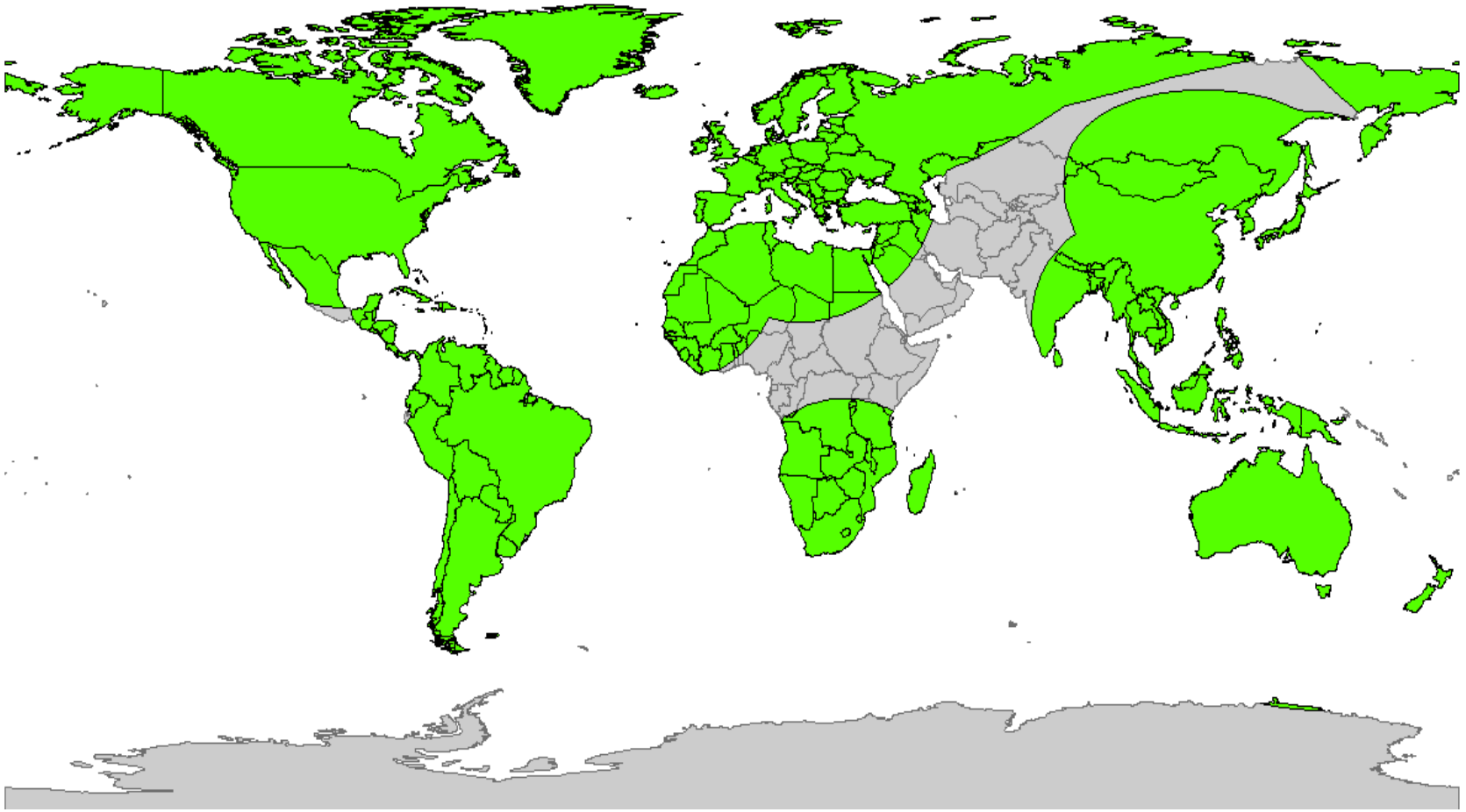
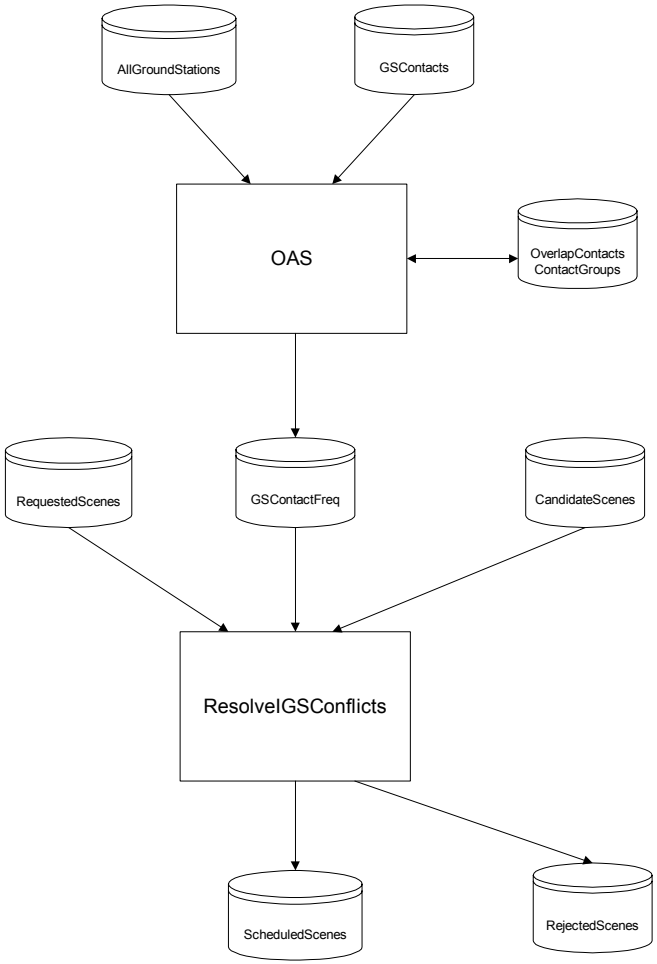
X-band Downlink Coverage Area



Optimal Antenna Selection (OAS)

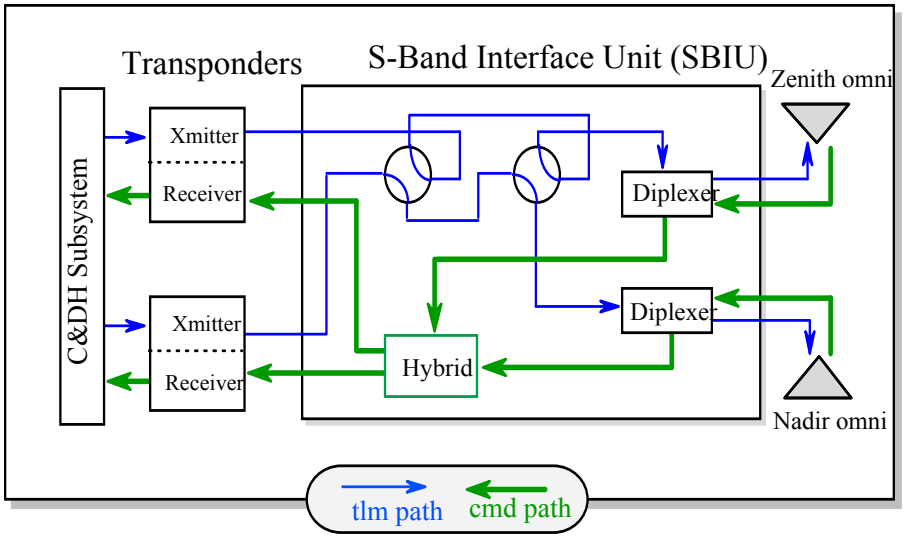


- Mission Planning is performed daily utilizing a Scheduling system to manage our spacecraft asset, capabilities, limitations, and downlink requirements. Scheduling takes the following into account:
  - Long Term Acquisition Plan
  - Cloud cover predictions
  - Flight Dynamics products
  - ETM+ calibration requests
  - OAS
  - Special or Individual User Requests
- OAS is an additional functionality of the LANDSAT 7 Scheduler.
- OAS's objective is to increase the number of scenes provided to the Landsat and the International Ground Stations maximizing spacecraft and ground capabilities.
- This will be achieved using alternative x-band frequencies.
- L7 has 4 transmitters, 3 antennas, and 3 transmit frequencies that are selectable and cross-strap able.
- No two antennas can transmit on the same frequency to IGS stations at the same time.
- When two overlapping stations compete for the same scene image on the same frequency, OAS assess the frequency capability of the stations and assigns a GXA and frequency.

Additional Transmit and Receive Information

- Landsat 5
  - S-band NASA Standard Transponder for TT&C
  - Direct Access S-band (DASB) for MSS only
  - Ku-band Transmitter for output through TDRSS
- Landsat 7
  - S-band NASA Standard Transponder for TT&C

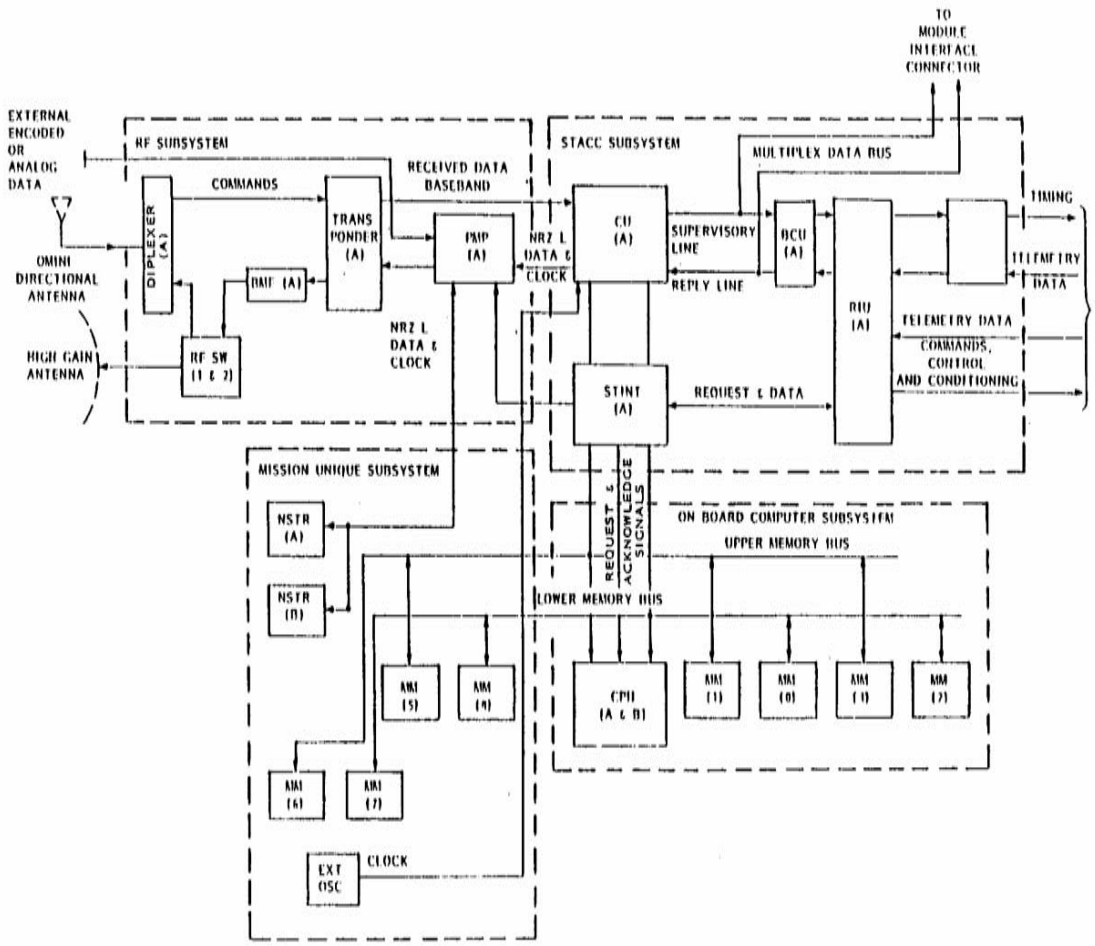
Landsat 7 S-band System: Transmit and Receive



- S-band: Receive
  - The S-Band receiver receives 2106.40625 MHz signals passed from the omni antenna.
  - Both receivers see the signals from both antennas.
  - Receivers are automatically set to either TDRS or STDN mode based on the received signal.
  - In STDN mode the command rate is 2000 bps.
  - In TDRS mode the command rates are 125 bps and 1000 bps.

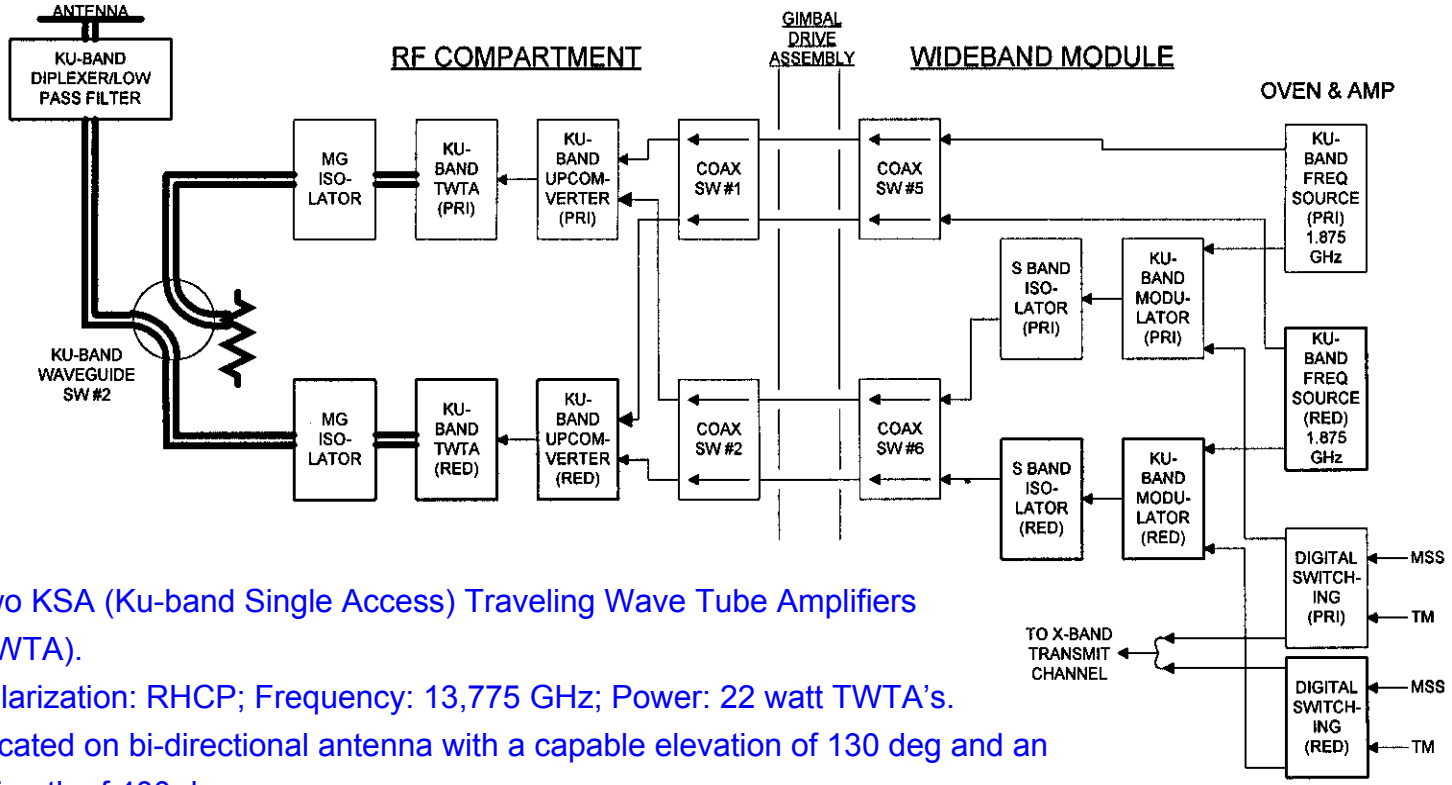
- S-band: Transmit
  - OMNI Antenna meaning radiates in all directions
  - Two Transmitters; 1 in zenith (Space) and 1 nadir (Earth)
  - The transmitters can be commanded to operate in coherent or non-coherent mode.
  - The S-Band transmitter produces a 5 Watt RF signal at 2287.5 MHz with a 240/221 coherent uplink ratio.
  - The S-Band system transmits all housekeeping telemetry and accepts all commands. The S-Band system also provides SN tracking and SN and ground doppler capabilities.
  - The output from the S-Band system is Left-Hand Circular Polarized (LHCP).
  - Real-time transmit data rate is 1.216 kbps and 4.864 kbps and 256 kbps for SSR housekeeping playback.
  - BPSK on 1.024 MHz subcarrier and QPSK on I and Q channels (1:1)

Landsat 5 S-band System: Transmit and Receive



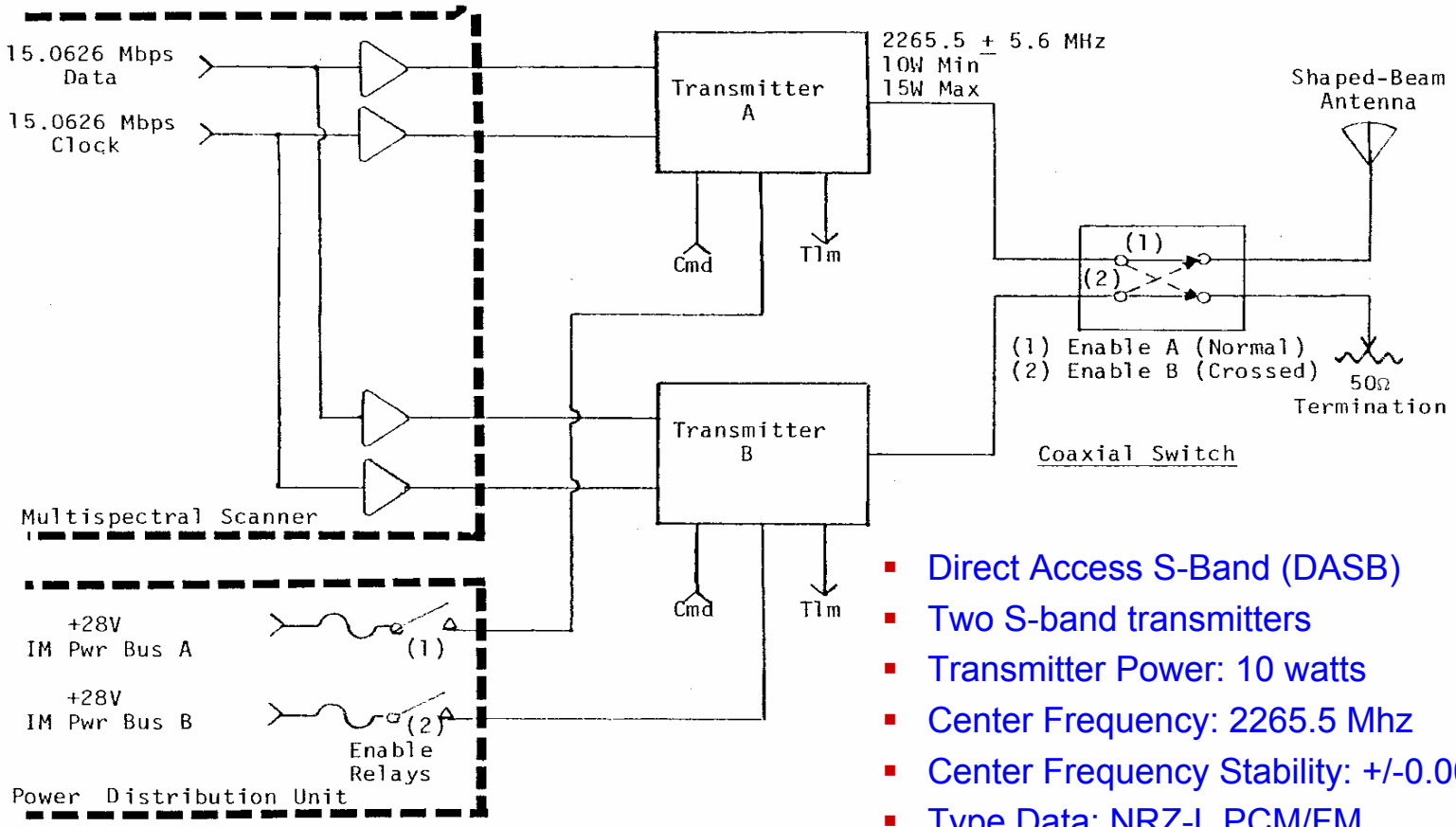
- Receive Frequency: 2106.4 MHz
- EIRP: +/- 3.2 dBW
- Transmit Frequency: 2287.5 MHz
- RF Power: 5 watts
- Coherent Turn Around Ratio: 240/221
- PCM/PSK/PM modulation 8 kbps telemetry data on 1.024 MHz subcarrier
- PCM/PM modulation 32 kbps Payload Correction Data phase modulated on carrier
- TDRSS Ground Command Rate: 125 and 1 kbps
- GSTDN Ground Command Rate: 2 kbps
- Command Format: NRZ-M, 16 kHz subcarrier
- Telemetry Rates: SQPN/QPSK
  - Realtime: 1 and 8 kbps
  - OBC data: 32 kbps
  - Tape recorder Playback: 256 kbps
- L-band receiver for GPS capability not utilized.

Landsat 5 Ku-band System: Transmit Only



- Two KSA (Ku-band Single Access) Traveling Wave Tube Amplifiers (TWTA).
- Polarization: RHCP; Frequency: 13,775 GHz; Power: 22 watt TWTA's.
- Located on bi-directional antenna with a capable elevation of 130 deg and an azimuth of 400 degrees.
- Tracking speed is 0.06 deg/s and slew speed is 1.406 deg/s.
- Autotrack and Program track capable via 1.8 High Gain Antenna.
- Primary and Redundant K-band TWTA's have reached nominal end of life at a Helix Current value of 2.0 mamps.
- Investigation and testing has revealed that the KSA TWTA's may be recoverable.

Landsat 5 DASB System: Transmit Only



- Direct Access S-Band (DASB)
- Two S-band transmitters
- Transmitter Power: 10 watts
- Center Frequency: 2265.5 Mhz
- Center Frequency Stability: +/-0.005%
- Type Data: NRZ-L PCM/FM
- MSS Data Rate: 15.06 Mbps